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The 'Hip Vacuum Sign'—a new radiographic phenomenon in femoro-acetabular impingement

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ABSTRACT

Femoro-acetabular impingement (FAI) is a frequent cause for groin pain in young and active patients. We discovered a so far undescribed radiographic phenomenon only visible in frog-leg lateral radiographs. The aim of this study was to describe this new radiological sign, to determine its prevalence in a symptomatic population and to investigate the correlation to a potential underlying pathology. We retrospectively reviewed all patients, who had been sent to our clinic between 2010 and 2012 for hip complaints. We excluded patients older than 50 years and patients with advanced osteoarthritis. Two independent investigators blinded to clinical data independently examined all images for the presence, location and dimension of a vacuum phenomenon and a potential underlying hip pathology. We included 242 patients. 137 of them showed clinical and radiological signs of FAI. A hip vacuum phenomenon was identified in 20 of 242 patients (8%). Interestingly, all these patients showed distinct signs of femoro-acetabular impingement. In reference to this, the prevalence of the "Hip Vacuum Sign" was 15% (20/137) in symptomatic patients with FAI. There was no correlation with age or gender. We identified a new radiological sign, the "Hip Vacuum Sign", in 15% of symptomatic patients with FAI. It was only visible in frog-leg lateral radiographs. We suggest that it represents a subluxation of the femoral head due to a lever mechanism between the femoral neck and the acetabular rim and is, therefore, a hint for a relevant femoro-acetabular impingement mechanism.

INTRODUCTION

Femoro-acetabular impingment (FAI) is a risk factor for developing early labral and cartilage damage with subsequent osteoarthritis of the hip joint. It has a high prevalence in young and active patients and typically presents with activity related pain mainly in the groin [1–3].

FAI appears in different types: cam-type-lesions show a loss of the femoral head-neck offset, while pincer-type-lesions usually present with acetabular overcoverage. These anatomical abnormalities result in an early mechanical conflict between the acetabular rim and the head-neck junction.

Radiologic deformities that cause FAI are quiet common. They were found in 14–35% of asymptomatic population [4]. In patients with hip pain or symptomatic labral tears, the prevalence is up to 90% [5, 6].

Diagnostic radiology plays a major role in identifying the underlying pathology and conventional radiographs are standard in FAI diagnostics. Besides the obligatory anterior-posterior view of the pelvis at least one further lateral projection is mandatory to assess the structural abnormities of the femoral head/neck junction. In general, the lateral cross table view has been established as a standard over the last years. Alternatively the frog-leg lateral radiograph or the Dunn-view can be used.

We use the frog-leg lateral view as the standard secondary plane because it was shown be the most reliable to diagnose FAI compared to anterior-posterior and cross-table radiographs and has a lower exposure of radiation than the cross-table view [7, 8].

We noticed a so far unknown radiological sign in the joint cavity of frog-leg lateral radiographs in hips of symptomatic non-arthritic young adults. The aim of this study was to describe this new radiological sign and to determine the prevalence of this phenomenon in symptomatic patients.

MATERIAL AND METHODS

Patient data

We reviewed all patients who attended our out-patient clinic with hip complaints between 2010 and 2012. The radiographs were retrieved of from our Picture Archiving and Communication System (PACS). All information about the patients, including their age, gender and the medical history, were received from their medical records in our database. Final diagnosis was made in carefully analyzing the association of patient history and physical examination with radiographic imaging.

Inclusion and exclusion criteria

We included all patients under 50 years of age without advanced osteoarthritis (Kellgren and Lawrence (K&L) grade ≤ 2) of their hip joints with a complete set (a.p. and frog-leg-lateral view) of high quality radiographs in our PACS. We excluded all patients with a history of previous hip surgery or imported external taken radiographs due to potential differences in the imaging technique.

Obtaining the radiographs

All radiographs were performed by orthopedic radiology technicians in our radiology department. The anterior-posterior view of the pelvis was taken with the patient supine. The X-ray beam was centered on the symphysis pubis in the vertical midline. The legs were parallel with the feet slightly internal rotated and separated approximately one shoulder width apart.

The frog-leg lateral view was taken with the patient supine. The hip is in 45° flexion, 45° abduction and external rotation. The ipsilateral knee of the patient is flexed so the bottom of the foot was placed on the contralateral leg at the level of the knee. The leg then was externally rotated. The X-ray beam was directed from anterior to posterior and centered on the femoral head (Fig. 1) [7].

All radiographs were recorded due to a medical indication and informed consent for the study was waived from the institutional review board.

Review and analysis of radiographs

All radiographs were independently reviewed for the occurrence and the morphology of a vacuum phenomenon by two of the authors (N.M. and J.S.). They were blinded to clinical data. The data was compared with the information provided in the patient's records (age, gender and diagnosis). The frequency of the "Hip Vacuum Sign", the dimensions and the average values in all radiographs were determined. Besides radiological signs for a FAI were measured defined by an α angle $>55°$ [9] and a femoral head-neck offset < 10 mm in lateral radiographs for cam impingement and a lateral center edge angle $> 39°$ for pincer impingement. Cohen's kappa test was performed to identify the intra- and the inter-observer variability.

Fig. 1. Technique used performing radiographs in the frog-leg lateral view.

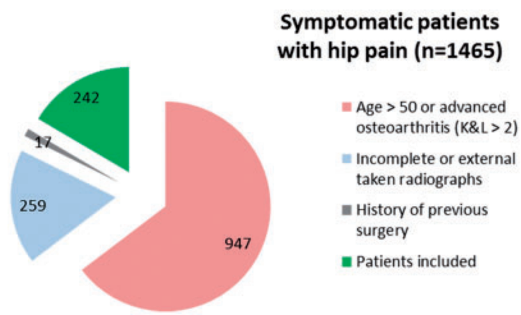

Fig. 2. Pie chart displaying the distribution of included and excluded patients.

Statistical section

A χ^2-test was performed to identify whether women or men are predominantly affected. A *t*-test was done to compare the ages of HVS positive and HVS negative patients.

RESULTS

About 242 patients of 1465 screened patients fulfilled the inclusion criteria. Most of most patients were excluded because of age or advanced osteoarthritis (Fig. 2). We diagnosed a "Hip Vacuum Sign" (HVS) in 20 of these 242 patients (8.2%). The intra-observer variability was 0.99 and the inter-observer variability was 0.98. The HVS was only detected in the frog-leg lateral view and typically presents as a narrow and hypodense stripe situated in the central

Fig. 3. Anterior-posterior and frog-leg lateral radiographs of a patient with symptomatic femoro-acetabular impingement. While no vacuum phenomenon can be found in the anterior-posterior radiograph (A) and in the magnified a.p.-view of the right hip (B), a vacuum phenomenon appears in the frog-leg lateral projection (C).

superior part of the joint cavity (Fig. 3). The size is variable with an average length of 30.3 mm (±8.4 mm) and an average thickness of 0.6 mm (±0.1 mm). The different degrees in presentation of the phenomenon are depicted in Fig. 4.

One hundred and thirty-seven of the 242 patients showed clinical and radiologic signs of a femoro-acetabular impingement. All radiographs revealing the HVS were in this subgroup of patients and showed clinical and radiological features of a femoro-acetabular impingement. Thus 20 of 137 FAI-cases presented the HVS (14.6%).

In nine of these 20 HVS-positive patients, hip arthroscopy was performed in our clinic. In all patients who underwent surgical correction of FAI, the HVS disappeared after surgery (Fig. 5).

By reviewing the medical records of HVS positive and HVS negative patients, we found no significant difference in age between the two groups (38.5 in HVS positive vs. 38.9 in HVS negative cases, $P = 0.89$, *t*-test). In addition, we found no significant gender association with the hip vacuum phenomenon. Nine of the 20 patients showing the HVS were female (45%, $P = 0.75$, χ^2-test).

DISCUSSION

We describe a new radiographic sign that we call the "Hip vacuum sign" and investigated the prevalence in symptomatic patients. The HVS was seen in 20 of the 242 patients (8%). Interestingly the radiological sign was only traceable in patients with femoro-acetabular impingement with a prevalence of 14.6% (20 of 137).

Vacuum phenomena are reported to appear in different joints e.g. the spine, shoulder or knee [10–12]. They can be observed studying joints under traction or in degenerative disorders. In some cases, like in spine or shoulder, they are linked to instability of the joint [13, 14]. A vacuum sign in the hip is well known to appear under traction during hip arthroscopy. Under these conditions, traction forces between 400 and 600 N are usually required to generate the vacuum phenomenon at the hip [15]. Forces may be significantly less in situations of ligamentous laxity or hip instability [16, 17].

Up to now, there exists no description of a vacuum sign at the hip joint simply caused by a static leg position in the physiological range of motion like in the frog-leg lateral view. We postulate that the vacuum phenomenon is caused due to a lever mechanism between the acetabular rim and the femoral neck in femoro-acetabular impingement [4].

In a recent study, the hip motion was visualized dynamically in extreme flexion, abduction and external rotation using dynamic computed tomography and the results were compared with intra-operative findings [18]. The authors observed a subluxation of the femoral head in 40% of patients with anterior impingement and 70% of patients with posterior impingement. In addition, it was suggested that all FAI subtypes and supraphysiological hip motions can lead to subluxation. This was confirmed by Kolo *et al.* who observed a high rate of hip subluxation during dance movements in end range hip motion, using MRI-based anatomical 3D models and gait analysis [19]. Another reason for suggesting a hip subluxation in patients with femoro-acetabular impingement has been reported recently by Steppenbacher *et al.* The authors analyzed morphologic features of the hip in patients after

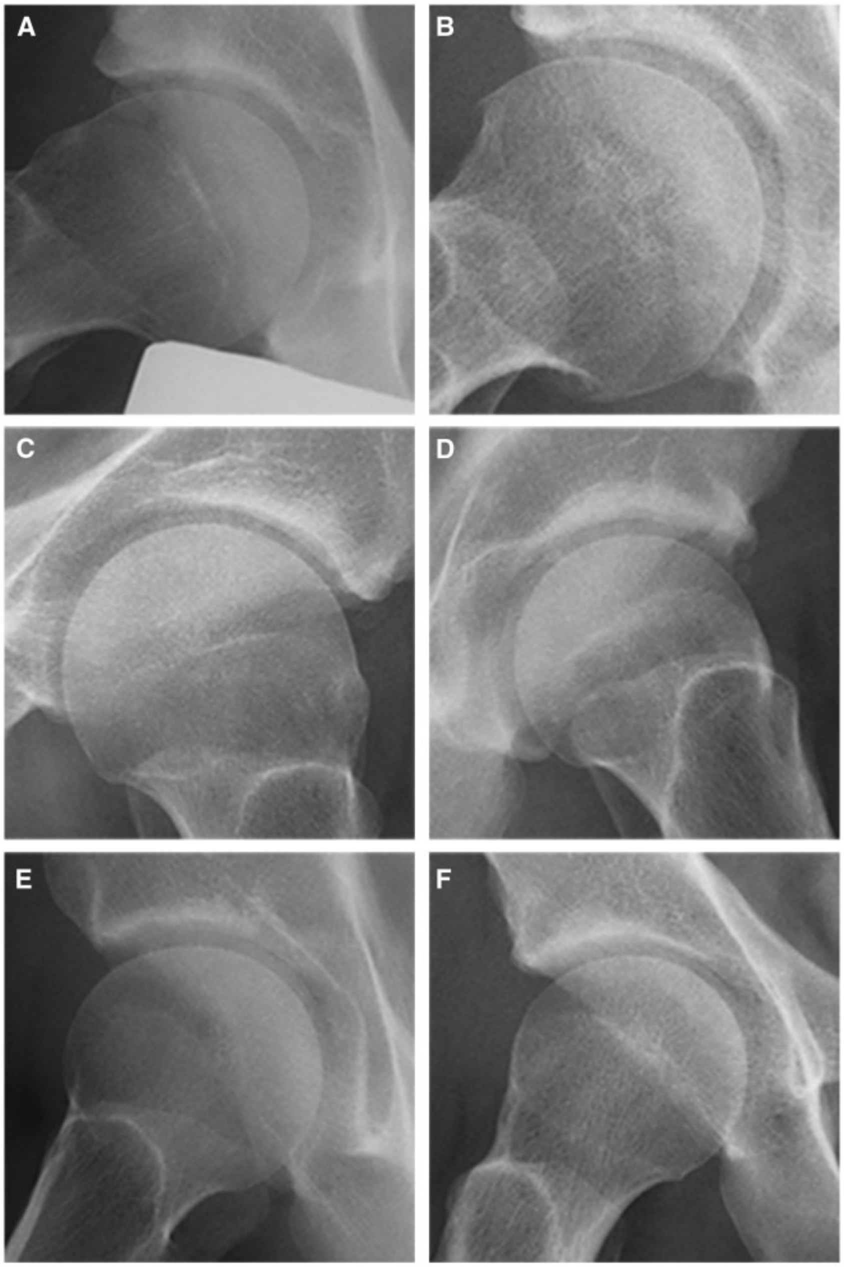

Fig. 4. Frog-leg lateral radiographs show the different degree of variation of this phenomenon. In most cases the vacuum sign appears as a narrow stripe leading through the joint cavity like in A, C, D and E. Images F and B represent the smallest (F) and largest (B) recognizable example of the finding.

a traumatic hip dislocation and revealed an association between FAI deformities and traumatic hip dislocation [20, 21].

The findings emphasize our hypothesis that the hip vacuum sign represents a subluxation or at least a distraction of the femoral head due to an underlying femoro-acetabular impingement mechanism.

Surprisingly, the HVS was seen in the frog-leg lateral radiographs in a conscious patient. This is a static position in a physiological range of motion of the hip and is not the brief result of a dynamic movement or a forced or extreme flexion or abduction. Therefore, an acquired hip instability could be a relevant issue, as it was described by Tibor or Hammoud [4, 22].

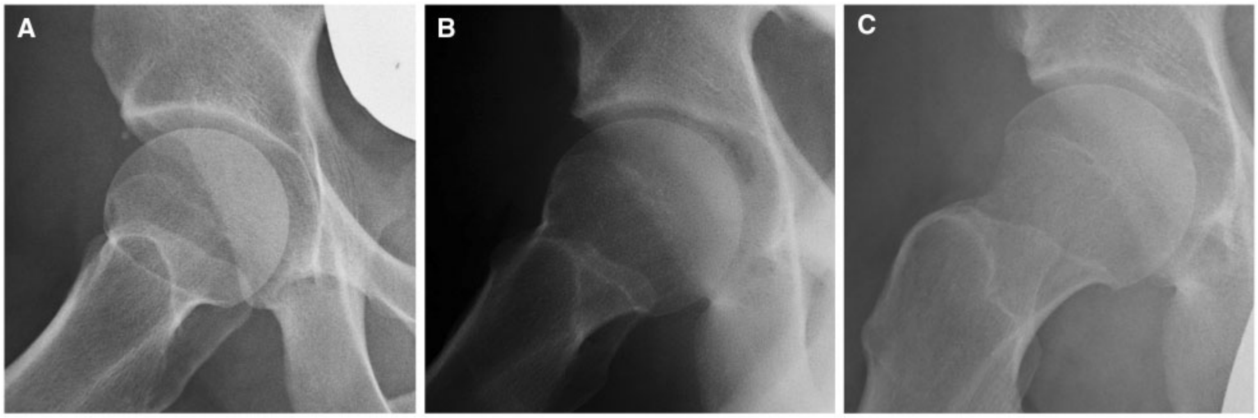

Fig. 5. Frog-leg lateral radiographs of two patients with symptomatic femoro-acetabular impingement. In (A), the exemplary morphology of a hip with femoro-acetabular impingement is shown (e.g. reduced femoral head neck offset). In (B), additionally, the hip vacuum sign is visible as a narrow zone with lower density traversing through the joint cavity. In (C), the same patient is shown after surgical correction of FAI. The HVS disappeared.

We believe that the hip vacuum sign is an important hint in diagnostic imaging for a relevant femoro-acetabular impingement mechanism and furthermore could be a hint for a hip instability.

In comparison with other radiographic signs associated with FAI e.g. the cross-over sign or herniation pits, the HVS has a lower prevalence. Laborie *et al.* [23] found the cross-over sign in about 50% of patients with FAI. Herniation pits were found in 85 of 200 patients in a study by Panzer *et al.* [24]. These radiographic phenomena may indicate an impingement mechanism but the reliability was recently doubted by different authors [25, 26].

There are several limitations to our study. In a retrospective study design, we included only symptomatic patients. In addition, the patients cannot be manipulated beyond the positioning of the original radiograph. This problem was addressed by excluding external radiographs from the study. Furthermore the acquisition technique of the frog-leg lateral view could be relevant. However, the HVS was also seen in external taken X-rays and is also visible in X-rays shown in publications about femoro-acetabular impingement from other groups [7, 27–30].

The occurrence of the “Hip Vacuum Sign” was seen in symptomatic patients with femoral acetabular impingement in the frog-leg lateral view. We suggest that it indicates a subluxation of the femoral head that might confirm the existence of a relevant femoro-acetabular impingement mechanism in a situation of acquired hip instability. In patients with hip pain and a positive HVS, a high suspicion for FAI exists and a further diagnostic evaluation of the patient is recommended.

Further research is required to better characterize the underlying constitution leading to femoral head subluxation in order to fully understand the etiology and clinical impact of the radiological vacuum phenomenon.

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